



# TILMedia Suite

Software package for calculating the properties of thermophysical substances



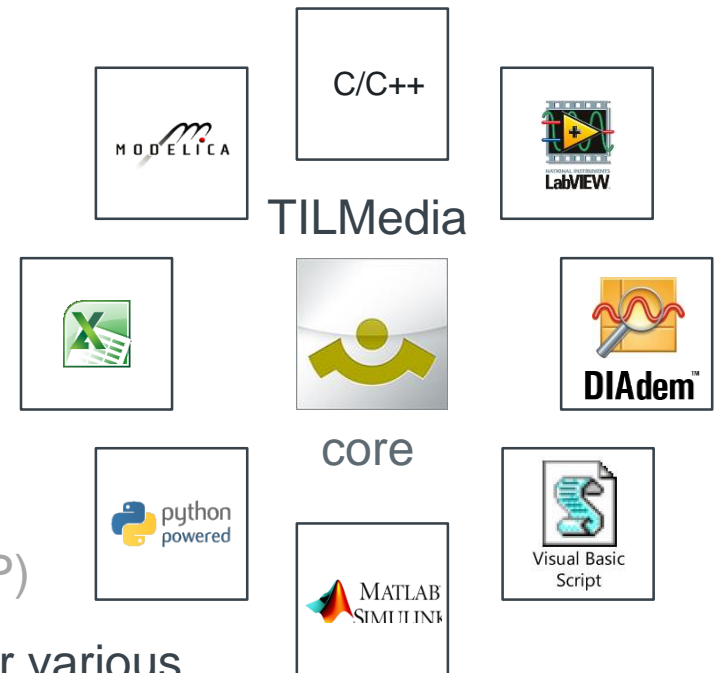
# TIL Media

## Substance properties optimized for stable and extremely fast dynamic simulations

- Calculation methods to express thermophysical properties of:

- L** Incompressible Liquids
- G** Ideal Gases
- VLE** Real Fluids (with vapor liquid equilibrium)
  - Mixtures

- Optimized mathematical equations with extremely high calculation speeds and high accuracies
- Several hundreds of substances available (also from external sources e.g. REFPROP)
- TILMedia Suite interfaces one property core for various software





# TILMedia as an Interface

## Fluid Properties

- Optimized own implementations for transient simulations
  - Equations of State
  - Set of curves
  - Table-based properties
- Implementations described in the literature:
  - VDI-Heat Atlas
  - VDI-Guideline 4670
  - NASA Glenn coefficients
- External Libraries e.g. REFPROP



## TILMedia Interfaces

- **VLEFluid** and VLEFluid Mixtures containing Vapor Liquid Equilibrium
- Incompressible **Liquid**
- Ideal **Gas** and Gas Mixtures



## Applications

- C/C++
- COM-Interface:
  - DIAdem
  - Visual Basic for Applications
  - VB Script
- LabVIEW
- MATLAB
- Simulink
- Microsoft Excel
- Modelica:
  - Dymola
  - MapleSim
  - OpenModelica
  - SimulationX
  - SystemModeler
- Python
- Not implemented yet



# VLEFluids

## Available thermophysical properties

Interface for fluids containing a Vapor Liquid Equilibrium

The following VLEFluid properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- mass fraction
- mole fraction
- average molar mass
- steam mass fraction (quality)
- specific isobaric/isochoric heat capacity
- isobaric thermal expansion coefficient
- isothermal compressibility
- Saturation properties, critical properties & properties on dew and bubble line
- speed of sound
- derivative of density with respect to specific enthalpy
- derivative of density with respect to pressure
- derivative of density with respect to mass fraction
- heat capacity ratio / isentropic expansion factor
- molar mass of one component in mixture
- Prandtl number
- thermal conductivity
- dynamic viscosity
- surface tension

As a function of:

- $p, h, x_i$     ▪  $p, s, x_i$
- $p, T, x_i$     ▪  $d, T, x_i$     with  $x_i=1$  for a single component



# Pure VLEFluids

## Approaches for simulation with Equations of State

- faster than REFPROP
- not exportable
- moderate memory requirement
- very good accuracy of calculations

### Available pure VLEFluids

- Ammonia
- Argon
- CO<sub>2</sub> (Span/Wagner and GERG)
- Ethanol
- Ethylbenzene
- M-Xylene
- Nitrogen
- Oxygen
- O-Xylene
- Propane
- P-Xylene
- R1234yf
- R125
- R134a (Tillner-Roth/  
Baehr and Astina/Sato)
- R143a
- R245fa
- R32
- R404A (PPF)
- R407C (PPF)
- R410A (PPF)
- R507A (PPF)
- Water (IAPWS 1995)



# Pure VLEFluids

## Available fluids containing Vapor Liquid Equilibrium

### Implementations with sets of curves:

- very fast
- exportable
- low memory requirement
- good accuracy of calculations
- CO<sub>2</sub>
- R1234yf
- R134a
- R407C
- R410A
- Water

### Table based thermophysical properties\*:

- very fast
- exportable
- high memory requirement
- very good accuracy of calculations
- Air (PPF)
- Methane
- R134a
- Table based properties of all REFPROP-Fluids possible on demand.

\* Only available with the Modelica library TIL



# Available VLEFluids – REFPROP

## REFPROP (208 media, pure fluids and mixtures):

▪ 1-Butene	▪ DEE	▪ Krypton	▪ Novec7000	▪ R-115	▪ R-407B	▪ R-423A	▪ R-508B
▪ Acetone	▪ Decane	▪ (R-784)	▪ Octane	▪ R-116	▪ R-407C	▪ R-424A	▪ R-509A
▪ Air	▪ DMC	▪ MDN	▪ Orthohydrogen	▪ R-123	▪ R-407D	▪ R-425A	▪ R-510A
▪ Amarillo	▪ DME	▪ MD2M	▪ (R-702)	▪ R-124	▪ R-407E	▪ R-426A	▪ R-512A
▪ Ammonia	▪ Ebenzene	▪ MD3N	▪ Oxygen	▪ R-125	▪ R-407F	▪ R-427A	▪ (Lemy 134)
▪ (R-717)	▪ Ekofisk	▪ MD4N	▪ (R-732)	▪ R-134a	▪ R-408A	▪ R-428A	▪ R-744
▪ Argon (R-740)	▪ Ethane	▪ Methane	▪ Oxylene	▪ R-141b	▪ R-409A	▪ R-429A	▪ R-1216
▪ Benzene	▪ (R-170)	▪ (R-50)	▪ Parahydrogen	▪ R-142b	▪ R-409B	▪ R-430A	▪ R-1233zd
▪ Butane	▪ Ethanol	▪ Methanol	▪ (R-702p)	▪ R-143a	▪ R-410A	▪ R-431A	▪ R-1234yf
▪ (R-600)	▪ Ethylene	▪ Methyl	▪ Pentane	▪ R-152a	▪ R-410B	▪ R-432A	▪ R-1234ze
▪ C1-CC6	▪ (R-1150)	▪ Linoleate	▪ (R-601)	▪ R-161	▪ R-411A	▪ R-433A	▪ R-C318
▪ C2-Butene	▪ Fluorine	▪ Methyl	▪ Propane	▪ R-218	▪ R-411B	▪ R-434A	▪ RE143a
▪ C3-CC6	▪ Gifcoast	▪ Linolenate	▪ (R-290)	▪ R-227ea	▪ R-412A	▪ R-435A	▪ (HFE-143m)
▪ C4-F10	▪ H2S	▪ MM	▪ Propylene	▪ R-236ea	▪ R-413A	▪ R-436A	▪ RE245cb2
▪ (R-3-1-10)	▪ HCL	▪ Methyl Oleate	▪ (R-1270)	▪ R-236fa	▪ R-414A	▪ R-436B	▪ (HFE-245cb2)
▪ C5-F12	▪ Helium	▪ Methyl	▪ Propyne	▪ R-245ca	▪ R-414B	▪ R-437A	▪ RE245fa2
▪ (R-4-1-12)	▪ (R-704)	▪ Palmitate	▪ P-Xylene	▪ R-245fa	▪ R-415A	▪ R-438A	▪ (HFE-245fa2)
▪ C11	▪ Heptane	▪ Methyl	▪ R-11	▪ R-365mfc	▪ R-415B	▪ R-441A	▪ RE347mcc
▪ C12	▪ Hexane	▪ Stearate	▪ R-12	▪ R-401A	▪ R-416A	▪ R-442A	▪ (HFE-7000)
▪ C-F3-I	▪ HighCO2	▪ M-Xylene	▪ R-13	▪ R-401B	▪ R-417A	▪ R-443A	▪ SF6
▪ CO	▪ HighN2	▪ N2O (R-744A)	▪ R-14	▪ R-401C	▪ R-418A	▪ R-444A (AC5)	▪ SO2 (R-764)
▪ COS	▪ Hydrogen	▪ Neon (R-720)	▪ R-21	▪ R-402A	▪ R-419A	▪ R-500	▪ T2-Butene
▪ Cyclohexane	▪ (R-702)	▪ Neopentane	▪ R-22	▪ R-402B	▪ R-420A	▪ R-501	▪ Toluene
▪ Cyclopropane	▪ I-Butene	▪ NF3	▪ R-23	▪ R-403A	▪ R-421A	▪ R-502	▪ Water
▪ D2	▪ I-Hexane	▪ Ngsample	▪ R-32	▪ R-403B	▪ R-421B	▪ R-503	▪ Xenon
▪ D4	▪ I-Octane	▪ Nitrogen	▪ R-40	▪ R-404A	▪ R-422A	▪ R-504	
▪ D5	▪ I-Pentane	▪ (R-728)	▪ R-41	▪ R-405A	▪ R-422B	▪ R-507A	
▪ D6	▪ (R-601a)	▪ Nonane	▪ R-113	▪ R-406A	▪ R-422C	▪ R-508A	
▪ D2O	▪ Isobutanol	▪ Novec649	▪ R-114	▪ R-407A	▪ R-422D		

Table based (high-speed) properties can be created of all 208 REFPROP-Fluids on demand.



# VLE Fluid mixtures

## Variable mixture calculations:

- Fundamental Equations of State (very detailed, designed for transient simulations):
  - Ammonia and Water (Tillner-Roth & Friend)
  
- Cubic Equations of State:
  - Argon
  - CO<sub>2</sub>
  - Ethanol
  - Hydrogen
  - Nitrogen
  - Oxygen
  - Water
  - and many more (VDI-Wärmeatlas)
  
- All 273 REFPROP-Fluids with each other





# Liquids

## Available thermophysical properties

Interface for incompressible liquids

The following liquid properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- specific isobaric heat capacity
- isobaric thermal expansion coefficient
- derivative of density with respect to specific enthalpy
- Prandtl number
- thermal conductivity
- dynamic viscosity

As a function of:

- $p, h$
- $p, T$



# Available Liquids

- Polynomial fits, 1-dimensional, temperature dependent:
  - Addinol XW15
  - Glysantin (30%-60%)
  - Oil Aral 0W30
  - Oil 15W40
  - Propylenglykol (30%-50%)
  - SHC\_XMP320 (Syntetic gear oil)
  - Therminol 59
  - Therminol 66
  - Therminol D12
  - Tyfocor 30
  - Tyfocor 45
  - Tyfocorl 33
  - Water
  - Zitrec M10
  - Zitrec M20
  
- All liquid mediums listed in VDI-Heat Atlas



# Gases

## Available thermophysical properties

Interface for gases and gas-vapor mixtures

The following gas properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- mass fraction
- mole fraction
- average molar mass
- specific isobaric/isochoric heat capacity
- isobaric thermal expansion coefficient
- isothermal compressibility
- speed of sound
- relative humidity
- derivative of density with respect to specific enthalpy
- derivative of density with respect to pressure
- derivative of density with respect to mass fraction
- partial pressure of components
- mass fraction of gaseous condensing component
- Prandtl number
- thermal conductivity
- dynamic viscosity
- Saturation properties

As a function of:

- $p, h, x_i$
- $p, T, x_i$
- $p, s, x_i$  with  $x_i=1$  for a single component



# Available pure gases

- Approaches with Equations of State (high accuracy and fast):
  - Dry Air
  - Exhaust Gas
  - Diesel Exhaust Gas
- VDI-Guideline 4670:
  - Dry Air
  - Nitrogen
  - Oxygen
  - Argon
  - Neon
  - Water
  - Carbon Dioxide
  - Carbon Monoxide
  - Sulphur Dioxide
- All 275 mediums listed in VDI-Heat Atlas
- All 2024 mediums listed by NASA Glenn coefficients



# Gas mixtures

Variable gas mixture calculations with independent library choice (All pure gases can be mixed with each other):

- Approaches with Equations of State
- VDI-Guideline 4670
- VDI-Heat Atlas (275 media)
- NASA Glenn coefficients (2024 media)



# Moist Air

## Available thermophysical properties

Interface for moist air (specialized form of gas mixture)

The following moist air properties are provided:

- density
- specific enthalpy
- pressure
- specific entropy
- temperature
- molar mass
- specific isobaric heat capacity
- specific isochoric heat capacity
- partial pressures
- (saturation) water mass fraction
- (saturation) water content
- (saturation) humidity ratio
- relative humidity
- specific enthalpy 1+x
- specific enthalpy of pure gas
- specific enthalpy of vaporization
- specific enthalpy of desublimation
- Prandtl number
- thermal conductivity
- dynamic viscosity
- freezing point
- speed of sound
- mass fraction
- gaseous mass fraction
- isobaric thermal expansion coefficient
- isothermal compressibility
- density derivative WRT mass fraction
- density derivative WRT pressure
- density derivative WRT specific enthalpy

As a function of:

- p, h, xi
- p, s, xi
- p, T, xi
- p, T, humRatio
- p, T, phi



# Available Moist Air

- Moist Air – TLK and IfT:
  - Gas vapor mixture
  - Heat capacity of water is considered as constant
  - Condensing and ice build up realized by constant enthalpy of evaporation and constant enthalpy of fusion
  - Transport properties equal to those of dry air
  
- VDI-Guideline 4670 for Moist Air and combustion gases:
  - Gas vapor mixture
  - Condensing and ice build up realized by temperature dependent enthalpy of evaporation and temperature dependent enthalpy of fusion
  - Transport properties equal to those of dry air

# Example in Modelica

Input of e.g. medium name, enthalpy and pressure amongst others to calculate all thermophysical properties

Parameter	Value	Unit	Description
vLEFluidType	TILMedia.CO2		type record of the VLE fluid or VLE fluid mixture
computeTransportProperties	false		=true, if transport properties are calculated
computeVLEAdditionalProperties	false		Compute detailed vapour liquid equilibrium properties
computeVLETransportProperties	false		Compute detailed vapour liquid equilibrium transport properties
deactivateTwoPhaseRegion	false		Deactivate calculation of two phase region
h		J/kg	Specific enthalpy
p		Pa	Pressure
xi	vLEFluidType.xi_default		Mass Fraction of Component i



# Example in MATLAB

## Anwendungserweiterung

- TILMediaMatlab321x64.dll
- TILMediaMatlab321Win32.dll

## C/C++ Header

- TILMediaHeader4Matlab.h
- portable.h

## Class

- VLEFluid.m
- MoistAir.m
- Liquid.m
- Gas.m

## Function

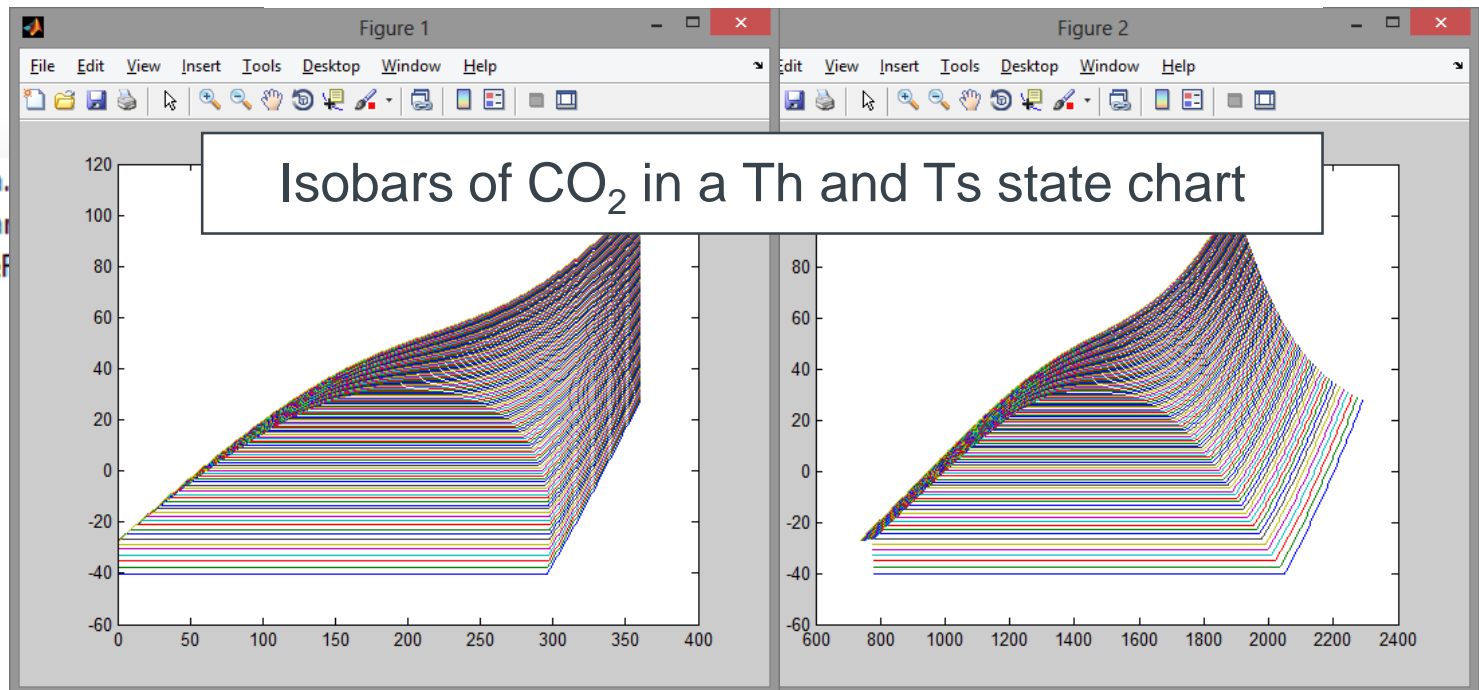
- loadTILMedia
- checkInputVar
- calcComputeF

*% TILMedia-functions:*

```
vle = VLEFluid();
hle = vle.setVLEFluidType(vle_name,1);
% Calculation-loop for thermophysical properties:
for i=1:length(p_vle)
    vle = vle.setState_phxi(p_vle(i)*ones(length(h_vle),1),h_vle);
    T_vle = [T_vle,vle.T];
    s_vle = [s_vle,vle.s];
end
```

*% Choice of substance:*

```
vle_name = 'CO2';
% Input of enthalpy- and pressure-range:
h_vle = [140:1:500]*1e3;
p_vle = [10:1:120]*1e5;
```



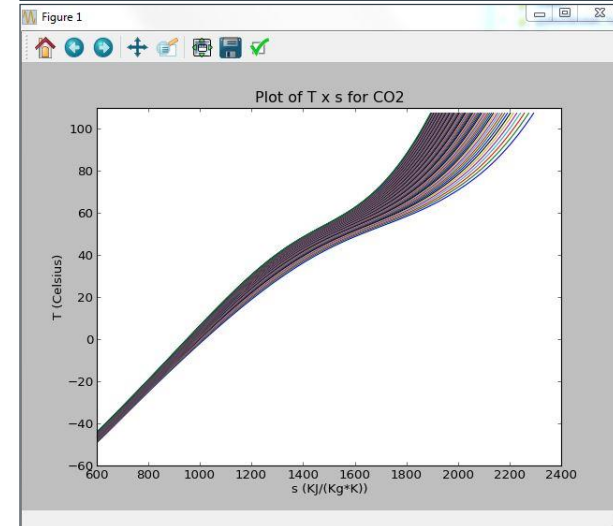
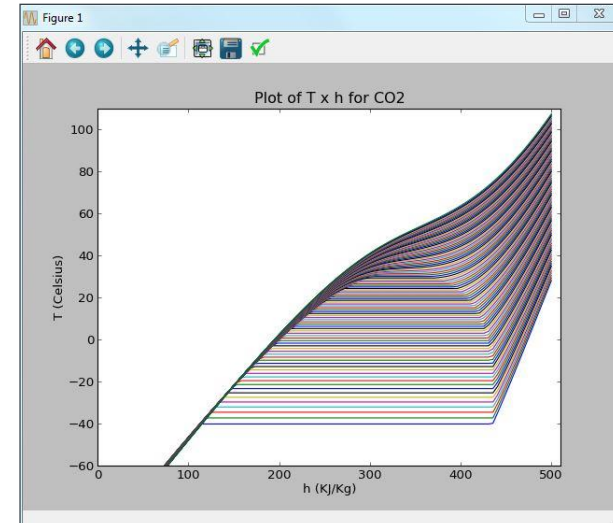


# Example in Python

## Isobars of CO<sub>2</sub> in the a Th- and Ts-chart

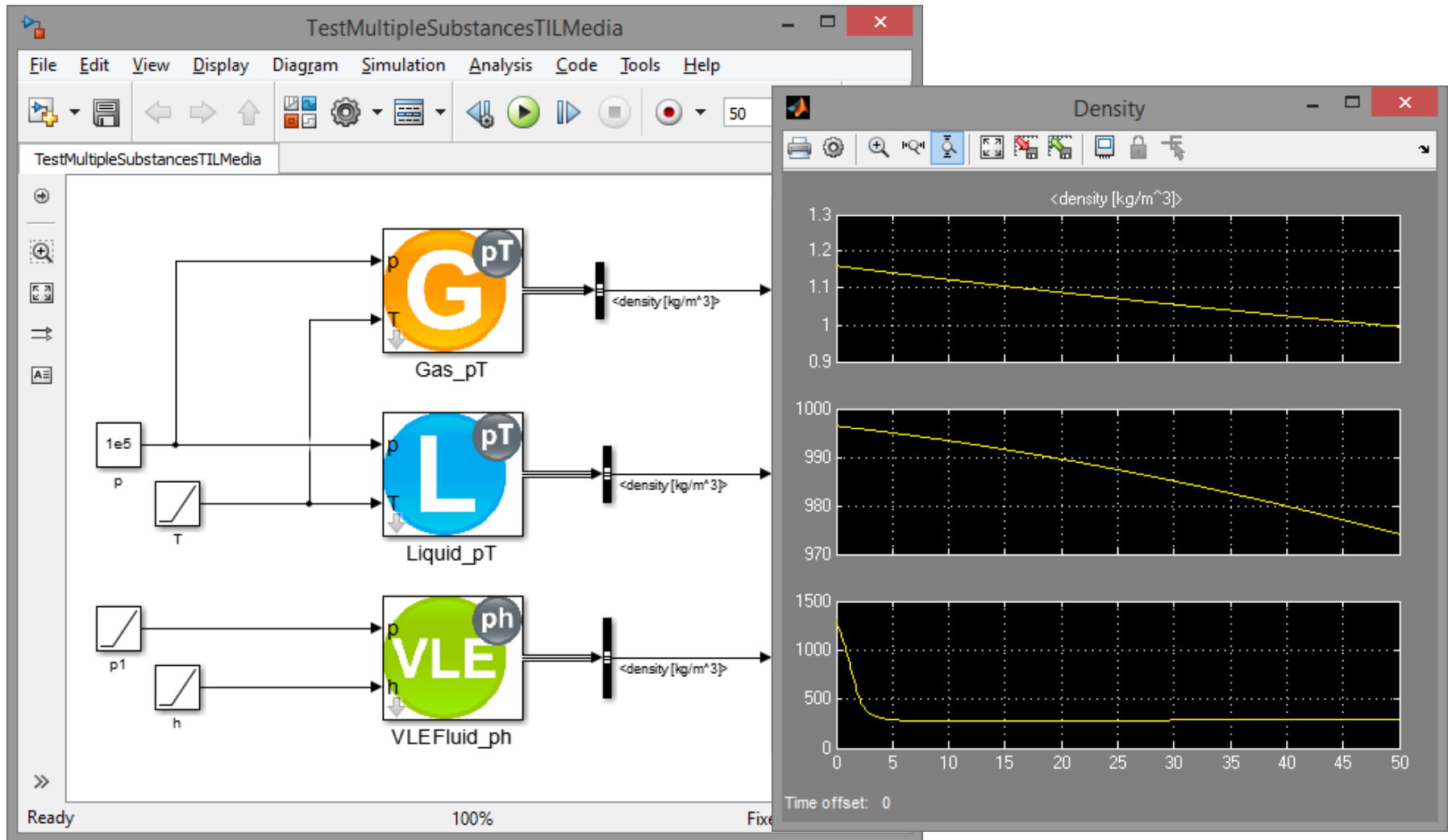
```
Spyder (Python 2.7)
File Edit Search Source Run Interpreters Tools View ?
Editor - F:\TILMedia\Isobar_T_x_h.py
Object inspector
Source Console Object Options
range
Definition : range(stop)
Type : Function of __builtin__ module
range(stop) -> list of integers
range(start, stop[, step]) -> list of integers
Return a list containing an arithmetic progression of integers. range(i, j) returns [i, i+1, i+2, ..., j-1]; start (!) defaults to 0. When step is given, it specifies the increment (or decrement). For example, range(4) returns [0, 1, 2, 3]. The end point is omitted! These are exactly the valid indices for a list of 4 elements.
Object inspector Variable explorer File explorer
Permissions: RW End-of-lines: CRLF Encoding: UTF-8-GUESSED Line: 4 Column: 19 Memory: 69 %

1 #isobar.py
2 import TILMedia
3 import numpy as np
4 import pylab as pl
5
6 nrElem_p = 100
7 nrElem_h = 100
8
9 p = np.linspace(10,120,nrElem_p) # bar
10 h = np.linspace(10,500,nrElem_h) # KJ/Kg
11 T = np.zeros(nrElem_h) # Celsius
12 vle = TILMedia.VLEFluid('Refprop.CO2')
13
14 for i_p in range(nrElem_p):
15     for i_h in range(nrElem_h):
16         vle.setState_phxi(p[i_p]*1e5,h[i_h]*1000)
17         T[i_h] = vle.T - 273.15
18     pl.plot(h,T)
19
20 # give plot a title
21 pl.title('Plot of T x h for CO2')
22 # make axis labels
23 pl.xlabel('h (KJ/Kg)')
24 pl.ylabel('T (Celsius)')
25 # set axis limits
26 pl.xlim(0, 510)
27 pl.ylim(-60.0, 110.)
28 # show the plot on the screen
```



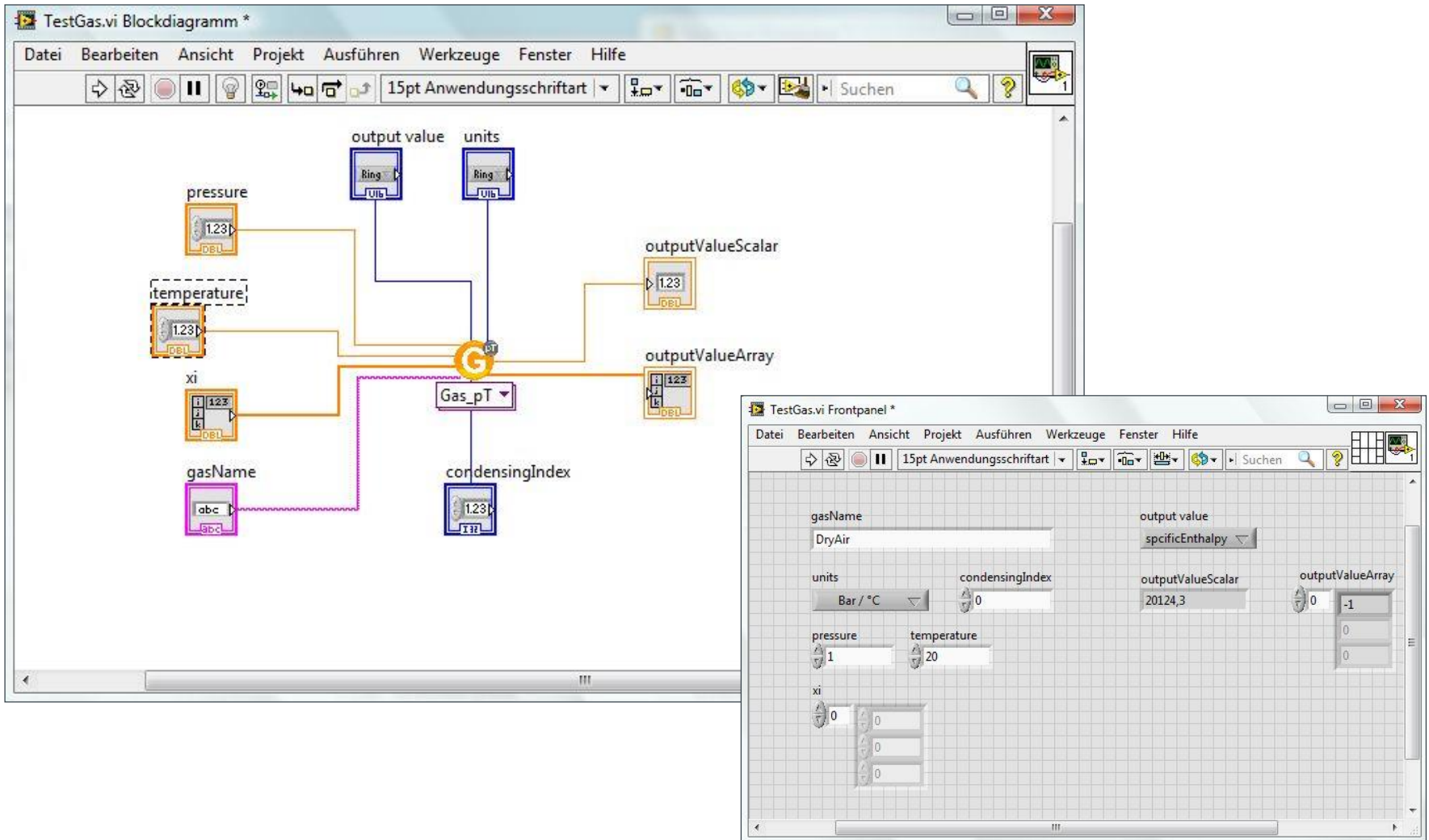


# Example in Simulink





# Example in LabVIEW



# Example in Excel

BEREICHE				
=Liquid_density_T(A3;C5)				
	A	B	C	D
1	<b>Description</b>	<b>Variable</b>	<b>Value</b>	<b>Unit</b>
2	<b>Inputs:</b>			
3	Glysantin_50			
4	Pressure	p	1.01E+05	Pa
5	Temperature	T	300	K
6	<b>Calculation:</b>			
7	Density	rho	=Liquid_density_T(A3;C5)	
8	Entropy	s	-567.3796701	J/(kg K)
9	Enthalpy	h	89323.76775	J/kg
10	Specific isobaric heat capacity	cp		
11	Isobaric thermal expansion coefficient	beta		
12	Dynamic viscosity	eta		
13	Thermal conductivity	lambda		
14	Prandtl number	Pr		

Calculation of density of water-glycol 50:50 at 300 K (and normal pressure)

**Funktionsargumente**

Liquid\_density\_T

LiquidName  = "Glysantin\_50"

T  = 300

= 1065.506241

'Density' in [kg/m^3] as a function of T.

**LiquidName** Liquid name.

---

Formelergbnis = 1065.506241

[Hilfe für diese Funktion](#)



# Examples using Windows COM-Interface

## Visual Basic for Applications (VBA) and Visual Basic Script (VBS)

```
'creating two variables
Dim obj, msg As String
'creating a liquid-object
Set obj = CreateObject("TILMedia.Liquid")
'set medium to water-glycol-mixture 50:50
Call obj.setLiquidType("Glysantin_50")
'calculating properties with pressure = 1
    bar and temperature = 300 K
Call obj.setState_pTxi(1e5, 300)
'constructing a message:
msg = "The density of Glysantin_50 is "
    + str(obj.d)
msg = msg + " under the conditions
    pressure = " + str(obj.p)
msg = msg + " and temperature = "
    + str(obj.T)
MsgBox msg 'displaying a message
```

## DIAdem

```
'loading a data file with values for pressure
    and temperature
Call DataFileLoad(CurrentScriptPath
    &"Example_pT.TDM", "TDM", "Load")
'creating four variables
Dim obj, array_p, array_T, chnName_d(0)
'creating a vector-liquid-object
Set obj = CreateObject("TILMedia.VectorLiquid")
'set medium to water-glycol-mixture 50:50
Call obj.setLiquidType("Glysantin_50")
'store pressure values of channel to array
array_p = ChnToValue("channelName_p")
'temperature values from channel to array
array_T = ChnToValue("channelName_T") Call
'calculating properties with pressure and
    temperature array in SI units
obj.setState_pTxi(array_p, array_T)
'set new channel name (vector) to "density"
chnName_d(0) = "density"
'saving density values in channel
Call ArrayToChannels(obj.d, chnName_d, true)
```

red colored = DIAdem-specific functions

# Thank You



If you have any questions,  
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